of a downshift into GR−1 and comparing that estimated speed to the maximum downshift engine speed (ES_{MAX}). If ES GR−1 is less than the maximum downshift engine speed ($ES_{GR-1}<ES_{MAX}$), then a single downshift from the currently engaged ratio (GR) into GR−1 is desirable and will be commanded. If not,

(4) No downshift will be commanded.

To provide for enhanced performance when performance is requested by the operator (such as, for example, when throttle pedal displacement position is above a reference value (usually about 85–90%)), the desirable maximum engine speed (ES_{DES}) used to evaluate possible skip downshifts is increased by a performance offset (if THL>REF, then $ES_{DES}=ES_{DES-DEFAULT}$+offset). For a typical diesel engine having a rated speed of about 2100 RPM, the offset is equal to about 50–150 RPM.

Increasing the desirable maximum engine speed (ES_{DES}) used to evaluate skip downshifts will result in the selection of more performance-oriented gear ratios.

Alternatively, the value of ES_{DES} used to evaluate skip downshifts could be increased incrementally or continuously from the default value thereof as throttle position (THL) exceeds the performance reference value.

The control of the present invention is shown in flow chart format in FIGS. 3A and 3B. Although only skip shifts of two ratio steps are illustrated, the present invention also is applicable to skip shifts of three or more ratios.

The time and/or rate of engine acceleration (dES/dt) used to determine an estimated engine speed after a downshift (ES_{GR-N}) may be empirically determined constants or may be calculated or learned values.

To complete a downshift from GR to GR−N, the engine speed must be modulated to a zero driveline torque value (see U.S. Pat. No. 4,850,236), the transmission must be shifted into neutral, the engine must be accelerated to a substantially synchronous speed for the new ratio ($ES_{GR-N}=OS_{EXPECTED}*GR_{TARGET}$), and then the transmission must be shifted from neutral into the appropriate ratio.

Accordingly, it may be seen that an improved control system/method for controlling downshifting in an at least partially automated mechanical transmission system in a vehicle is provided.

Although the present invention has been described with a certain degree of particularity, it is understood that the description of the preferred embodiment is by way of example only and that numerous changes to form and detail are possible without departing from the spirit and scope of the invention as hereinafter claimed.

What is claimed is:

1. A method for controlling automatic downshifting in a vehicular automated mechanical transmission system (**10**) for a vehicle comprising a fuel-controlled engine (**12**), a multiple-speed mechanical transmission (**14**), and a controller (**28**) for receiving input signals (**30**) including one or more of signals indicative of throttle position (THL), engine speed (ES), engaged gear ratio (GR) and vehicle speed (OS), and for processing said input signals in accordance with with logic rules to issue command output signals (**32**) to transmission system actuators including a transmission actuator (**52**) effective to shift said transmission, said method including the steps of:

determining a default value for an engine speed reference value ($ES_{DES-DEFAULT}$), and, if a downshift from a currently engaged ratio (GR) is indicated ($ES<ES_{D/S}$), determining by said processing if a skip downshift from the currently engaged ratio is desirable by determining an estimated engine speed at completion of the skip downshift, comparing said estimated speed to said engine speed reference value (ES_{DES}), deeming said skip downshift desirable if said estimated speed is less than said engine speed reference value, and commanding the skip downshift if deemed desirable, said method characterized by:

(i) sensing throttle position (THL);

(ii) comparing said throttle position to a performance reference value (REF) equal to at least 80% of full throttle;

(iii) if (a) the skip downshift is deemed desirable and (b) said throttle position is less than said performance reference value (THL<REF), causing said engine speed reference value to equal the default value thereof ($ES_{DES}=ES_{DES-DEFAULT}$); and

(iv) if (a) the skip downshift is deemed desirable and (b) said throttle position exceeds said performance reference value, causing said engine speed reference value to equal the sum of an offset value and said default value ($ES_{DES}=ES_{DES-DEFAULT}$+offset), said offset value equal to about 50–150 RPM.

2. The method of claim **1** wherein said default value is about 1600 RPM and said engine is a diesel engine having a rated speed of about 2100 RPM.

3. The method of claim **1** wherein said default value is about 1600 RPM and said engine is a diesel engine having a rated speed of about 2100 RPM.

4. The method of claim **1** wherein said offset value has a fixed value.

5. The method of claim **1** wherein said offset value has a value which varies with throttle position.

6. A method for controlling automatic downshifting in a vehicular automated mechanical transmission system (**10**) for a vehicle comprising a fuel-controlled engine (**12**), a multiple-speed mechanical transmission (**14**), and a controller (**28**) for receiving input signals (**30**) including one or more of signals indicative of engine speed (ES), engaged gear ratio (GR) and vehicle speed (OS), and to process said input signals in accordance with with logic rules to issue command output signals (**32**) to transmission system actuators including a transmission actuator (**52**) effective to shift said transmission, said method including:

(a) determining, as a function of throttle position, a downshift engine speed ($ES_{D/S}$) at which a downshift from a currently engaged ratio (GR) is indicated;

(b) comparing engine speed (ES) to the downshift engine speed;

(c) determining a first engine speed reference value (ES_{DES}) and a second engine speed reference value (ES_{MAX}), said second engine speed reference value greater than said first engine speed reference value ($ES_{MAX}>ES_{DES}$); and

(d) if said downshift from said currently engaged ratio (GR) is indicated ($ES<ES_{D/S}$), in sequence:

(i) determining if a skip downshift of two ratios from the currently engaged ratio (GR_{TARGET}=GR−2) is desirable by determining an estimated engine speed at completion of said skip downshift of two ratios (ES_{GR-2}), comparing said estimated speed to said first reference value, deeming said skip downshift of two ratios desirable if said estimated speed is less than said first reference value ($ES_{(GR-2)}<ES_{DES}$) and commanding said skip downshift of two ratios if deemed desirable; if not,

(ii) then determining if a downshift of one ratio from the currently engaged ratio (GR_{TARGET}=GR−1) is

desirable by determining the expected engine speed at completion of said downshift of one ratio (ES_{GR-1}), comparing said estimated speed to said second reference value, deeming said downshift of one ratio desirable if said estimated speed is less than said second reference value ($ES_{(GR-1)}<ES_{MAX}$) and commanding said downshift of one ratio if deemed desirable; if not,

(iii) then retaining the transmission in the currently engaged ratio; said method characterized by:

(i) sensing throttle position (THL);

(ii) comparing said throttle position to a performance reference value (REF) equal to at least 80% of full throttle;

(iii) if (a) the skip downshift is deemed desirable and (b) said throttle position is less than said performance reference value (TLH<REF), causing said first engine speed reference value to equal a default value thereof ($ES_{DES}=ES_{DES-DEFAULT}$); and

(iv) if (a) the skip downshift is deemed desirable and (b) said throttle position exceeds said performance reference value, causing said first engine speed reference value to equal the sum of an offset value and said default value ($ES_{DES}=ES_{DES-DEFAULT}$+offset), said offset value equal to about 50–150 RPM.

7. The method of claim 6 wherein said default value is about 1600 RPM and said engine is a diesel engine having a rated speed of about 2100 RPM.

8. A control system for controlling automatic downshifting in a vehicular automated mechanical transmission system (10) for a vehicle comprising a diesel engine (12) having a rated speed of about 2100 RPM, a multiple-speed mechanical transmission (14), and a controller (28) for receiving input signals (30) including one or more of signals indicative of throttle position (THL), engine speed (ES), engaged gear ratio (GR) and vehicle speed (OS), and to process said input signals in accordance with with logic

rules to issue command output signals (32) to transmission system actuators including a transmission actuator (52) effective to shift said transmission, said control system including logic rules for determining a default value ($ES_{DES-DEFAULT}$) equal to about 1600 RPM for an engine speed reference value (ES_{DES}); and, if a downshift from a currently engaged ratio (GR) is indicated ($ES<ES_{D/S}$), determining by said processing if a skip downshift from the currently engaged ratio is desirable by determining an estimated engine speed at completion of the skip downshift, comparing an estimated speed to said engine speed reference value, deeming said skip downshift desirable if said estimated speed is less than said engine speed reference value ($ES_{(GR-2)}<ES_{DES}$), and commanding said skip downshift of two ratios if deemed desirable; said system characterized by logic rules effective for:

(i) sensing throttle position (THL);

(ii) comparing said throttle position to a performance reference value (REF);

(iii) if (a) the skip downshift is deemed desirable and (b) said throttle position is less than said performance reference value (TLH<REF), causing said engine speed reference value to equal the default value thereof ($ES_{DES}=ES_{DES-DEFAULT}$); and

(iv) if (a) the skip downshift is deemed desirable and (b) said throttle position exceeds said performance reference value, causing said engine speed reference value to equal the sum of an offset value equal to about 50–150 RPM and said default value ($ES_{DES}=ES_{DES-DEFAULT}$+offset).

9. The system of claim 8 wherein said offset value has a fixed value.

10. The system of claim 8 wherein said offset value has a value which varies with throttle position.

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